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ON THE PROPAGATION OF METER WAVES IN THE INTERPLANETARY SPACE

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SUMMARY

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This paper presents factual data on the propagation of radio-waves to 50 million km distances in the frequency of 183. 6 mc/s. The maximum possible radiowave attenuation in interplanetary space is estimated. A compilation is given of literature data on the propagation of radiowaves in interplanetary space.

INTRODUCTION

The propagation of radiowaves in interplanetary space was studied earlier by way of observation of radio emission from discrete sources. The data obtained by radioastronomers allowed a detailed study of fadings, conditioned by the effect of Earth's atmosphere. Information on radiowave scattering by the corona and the supercorona of the Sun has been obtained [1, 2]. An important conclusion derived by radioastronomers consisted in the assertion of absence of radiowave attenuation in interplanetary space.

It must be stressed, that the laws of radiowave propagation, obtained by radioastronomical methods, cannot be transferred without verification, to the conditions of monochromatic signal propagation. For example, it is impossible to obtain from radioastronomical data

* O RASPROSTRANENII METROVYKH RADIOVOLN V MEZHPLANETNOM PROSTRANSTVE

information on the width of the spectral line obtained after passing the interplanetary medium. Interference fadings can appear in the presence of multiradial propagation of monocromatic radiowaves; radiowaves with a white spectrum will not undergo fadings in this case. Of great interest also is the investigation of the dependence of radiowaves' group velocity on the state of interplanetary medium. Finally, the verification of the assertion of the absence of radiowave attenuation in interplanetary medium by way of direct measurement of the dependence of field intensity on the distance, is also required.

The character of radiowaves' interaction with the interplanetary medium can be estimated by applying the existing theory of radiowaves' propagation in plasma and of known data on electron concentration. These estimates show that the interplanetary medium exerts practically no effect on the conditions of VHF radiowaves' propagation. The making of such estimates assumes, that the theory, verified in the conditions of the Earth's ionosphere, will be valid in all details upon extrapolation of its conclusions to the case of interplanetary medium. It must be stressed, that wave attenuation, conditioned by plasma flow, by scattering of radiowaves on large-scale irregularities, by transformation of electromagnetic waves into magnetohydrodynamic ones and other mechanisms, is possible in the interplanetary medium. Taking into account these phenomena, practically absent in the ionosphere, one may expect additional effects of interplanetary medium on the propagation of radiowaves.

In connection with the above, it is of great interest to accumulate and systematize factual data on the conditions of radiowave propagation in the interplanetary medium. This work is devoted to the description of the results obtained along these lines by way of observing the signals from object Mars-1 (in 183.6 mc/s), and the analysis of the literature data.

* * *

1. MAXIMUM POSSIBLE VALUES OF RADIOWAVE ATTENUATION IN INTERPLANETARY SPACE

The dependence of energy/**flux**/on the distance was investigated by us using the regular measurements of the level of the received signal from the object Mars-1. The latter was determined by way of comparison with the receiver noises, and these were measured with the aid of a calibrated noise generator and also by comparison with radio emission of the source Cassiopea-A.
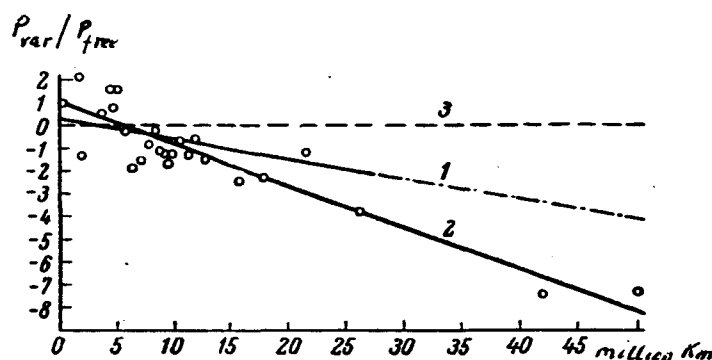

Fig. 1. - Dependence of signal level of object
Mars-1 with a frequency of 183 mc/s
on the remoteness.

The power of the airborne transmitter was controlled insufficiently reliably; however, the voltages fed and consumed by it, were maintained within given limits. The transmitting on-board antenna had a weak radiation pattern and the rotation of the object led to the appearance of slow fadings. Analysis of these fadings permits to exclude the effect of the radiation pattern of the airborne antenna on the results of measurements of signal level.

The dependence of received signal level, referred to values stemming from the law of free propagation of radiowaves, on the remoteness is plotted in Fig. 1. The line 1 is plotted by the method of least squares, using the data obtained at distances to 26 million km. The line 2 is plotted by using all data obtained at distances to 50 million km.

It must be noted that the measurements corresponding to distances from 26 to 50 million km are little reliable. The dashed line 3 corresponds to the law of free propagation of radiowaves. The materials obtained allow to estimate the maximum possible value in the attenuation of radiowaves of 183.6 mc frequency, when propagating in interplanetary space. It follows from Fig. 1 (line 1) that this quantity is equal to 4 ± 2 db. at 50 million km.

Because the study of the conditions of radiowave propagation was conducted by way of more than a single measurement of dependence of signal level on the distance (remoteness), an estimate of the conditions of propagation by other methods offers interest.

Data on the level of the received signal from object Pioneer V are brought up in [3]; the authors of this work note, that during observation of signals in the frequency of 378 mc/s, no notable deflection from the law of free propagation of radiowaves was observed at distances to 43 million km. However, the experimental data of [3], have a great spread, and they therefore do not point to the absence of radiowave attenuation, but permit to establish only the greatest possible attenuation, that might be concealed in the spread of experimental data. Analysis of these data shows that the attenuation of radiowaves in the frecuency of 378 mc/s is no more than 2 to 3 db at 43 million km.

The results of multiple determination of the effective cross section diameter of radiowave scattering in 700 mc/s, by planet Venus are brought out in [4]. The measured values of the effective scattering diameter were included in the 12 — 18 percent range. When conducting these measurements, the remoteness varied from 40 to 65 million km. Therefore, at radar location of Venus the total variation of the path of radiowave propagation constituted 50 million km. The maximum attenuation, which could have been concealed in the measurement errors of the effective scattering diameter, could not exceed 1.6 db at 50 million km in the course of these experiments.

For the studies of conditions of radiowave propagation in interplanetary medium particular interest is offered by observations of radio emission from the discrete source Taurus-A. This source is practically situated in the ecliptic plane. In connection with this, translucence of the interplanetary medium, comprised inside the Earth's orbit takes place at reception of its radio emission at various times of the year. Eclipse of this source by the Sun's corona takes place **every year** on or about June 14 - 15. Detailed data on the effect of corona and supercorona inhomogeneities on the propagation of meter radiowaves are brought up in works ref. [1, 2, 5, 6]. These works show that as the rays Taurus-Earth approach the Sun, a decrease takes place of the signal received by an interferometer with a large base. This signal decrease is interpreted as a consequence of the effect of irregularities of corona's electron concentration, leading to an increase of the source's angular dimension. Such explanation assumes that no decrease of Taurus-A radio emission will be observed at reception of the latter on an antenna with a radiation pattern width greater than 2°. It must be stressed, that direct data, which would have shown that at reception of radio emission from Taurus-A on an antenna of such radiation pattern width, no variation of the received power at annual motion of the Earth around the Sun would take place, are at present absent. The results of numerous measurements of radio emission flux from the source Taurus are brought out in [7]; these measurements show that the flux in the 100 — 300 mc/s band is practically constant and equal to $(1 - 2)\ 10^{-23}$ $w \cdot m^{-2} \cdot cps^{-1}$. Consequently, measurements of the flux at arbitrary points of the Earth's orbit show that at the distance of one astronomical unit the attenuation must be less than 3 db.

2. - ON THE EFFECT OF INTERPLANETARY MEDIUM ON THE PROPAGATION OF RADIOWAVES

The variation of solar activity must lead to a strong variation of the properties of interplanetary space. In connection with this, the comparison of even small effects of anomalies in the propagation of radio-

waves with the solar activity must present a great interest.

Observations of radio emission from the source Taurus-A [2, 5] show that irregular variations in the intensity of the signal received with radiointerferometers are revealed. Sudden decreases, as well as steady increases of the levels of the received signal are observed. These facts are naturally explained by the refractory effect of irregularities in the electron concentration. However, the possibility is not excluded of radiowave attenuation and amplification by ejections of the flowing plasma. These facts point to a possible multiple propagation of radiowaves with, as a consequence, the possibility of appearance of interference fadings at propagation of radiowaves in the interplanetary medium. It was shown in [8], that such fadings were apparently observed at signal reception from Pioneer-V.

Analysis of signals from Mars-1 in the frequency of 183.6 mc/s has shown, that no regular fadings were observed, which could be explained easily by object's rotation. Fadings have an irregular character, so that the explanation of their occurrence by the influence of either ionosphere irregularities or random rotations of the polarization plane on account of Faraday effect is rather difficult. Data on signal reception in the frequency of 183.6 mc/s from distances of the order of 0.2 million km are brought up in [9]; at the same time, regular fadings were observed, which could be easily explained by object's rotation. Therefore, it should be admitted, that an appearance of additional fadings, conditioned by the interplanetary medium, is possible at propagation of monochromatic radiowaves in the meter band over a distance of the order of tens of million km.

When conducting measurements of the dependence of the mean signal level on the distance (Fig. 1), it was revealed that the scattering of points exceeds the expected accuracy of measurements. - In connection with this, the deflection of the measured values of signal level from the averaged data (i. e. from the line 1, Fig. 1), was juxtaposed with the solar activity. The results of such comparison are plotted in Fig. 2. It follows from the latter, that the deflection of the signal level from average for several sessions, correlates with the solar activity. This preliminary result is based upon relatively few data, and thus calls for additional verification.

Experimental data are available [10], which show that the distance to Venus, measured by the radar method, correlates with the solar activity. This may be explained either by the assumption that the reflection takes place from the ionosphere of Venus, which varies its height, or by the admission, that the interplanetary medium exerts an influence on the group velocity. Radar location of Venus [10] was materialized in the frequency of 440 mc/s; thus, the assumption of the reflection from the ionosphere of Venus requires the admission of its electron concentration as being equal to $10^9 cm^{-3}$, i. e. 1000 times greater than in the Earth's ionosphere. Besides, radar location of Venus was also carried out in the frequencies of 700 and 2388 mc/s [11], and the measurements of the effective scattering diameter of Venus in the three indicated frequencies gave about an identical value. This makes little probable the assumption that the effect of solar activity on the time of radiowave propagation is linked with the variation of Venus' ionosphere height. The assumption of the influence of solar activity on the properties of the interplanetary medium, and, by way of consequence, on the group retardation of radiowaves, appears to us as more probable. This assumption meets also with the difficulties of [10].

A compilation of data on the value of the astronomical unit measured by radar and astronomical methods is presented in [13]. Comparison of these data points to a systematic difference in the values of the astronomical unit, determined by two methods. This also allows to suppose that the interplanetary medium affect the propagation of radiowaves.

At radiowave propagation in moving nonuniform medium, a widening of signal spectrum must take place. It was revealed at radar location of Venus in the frequency of 440 mc/s [12] that the spectrum of the reflected signal varied irregularly in time; this variation reached 0.5 cps,
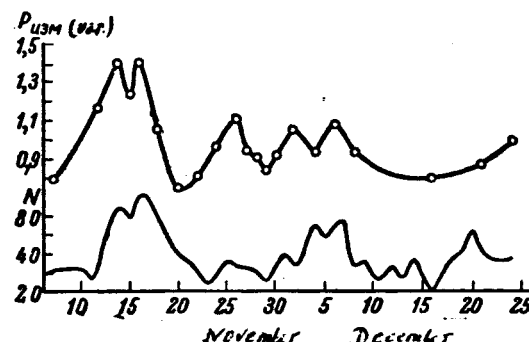

Fig. 2. - Correlation of the level of the received signal and of solar activity.

i. e. the relative width of the spectral line, apparently conditioned by the interplanetary medium's effect in that frequency, was of the order of $\Delta f / f = 10^{-9}$. Signals from object Mars-1 were observed in a system of narrow-band filters; these observation have shown, that the instantaneous width of the spectral line was no greater than $\Delta f / f = 2 \cdot 10^{-9}$.

* * *

CONCLUSIONS

Analysis of the described experimental data allows the following preliminary conclusions on the propagation of monochromatic radiowaves in the meter band over a distance of the order of 50 million km.

1.- Radiowave attenuation no greater than 2 — db.

2.- The interplanetary medium may induce the appearance of interference fadings.

3.- On the basis of the existing data one should estimate, that the widening of signal spectrum constitutes no more than $2 \cdot 10^{9}$.

4.- There exist experimental data pointing to a possible influence of solar activity on the level of the received signal and the range, determined by the radar method.

In conclusion, it should be stressed that the facts, described here, everyone of them separately, may be subject to doubt or explained by causes not related with the effect of the interplanetary medium on the propagation of radiowaves. However, the concomitance of all facts points to the representation of a "free propagation" of meter radiowaves in interplanetary space as being limited, and requiring further refinement.

*** THE END ***

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